Low Profile Inverted-F-L Antenna for 5.5 GHz WiMAX Applications

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Abstract—**This paper presents a novel low profile inverted-F-L antenna (IFLA) for worldwide interoperability for microwave access (WiMAX) applications by means of numerical simulation. The antenna has compact size of 9×20 mm² and provides a wide bandwidth of 750 MHz (5150~5900 MHz) which covers the 5.5 GHz WiMAX applications. Moreover it has very high peak gain of 8.04 dBi with 1.38 dBi gain variation within the 10 dB return loss bandwidth. The VSWR of the proposed IFLA varies from 1.79849 to 1.91245 within the antenna 10 dB return loss bandwidth. The antenna provides peak return loss of -29.903 dB at 5.45 GHz and the input impedance of proposed IFLA is 47.8595 Ω at 5.5 GHz.**

Index Terms— **Inverted-F Antenna (IFA), Inverted-F-L Antenna (IFLA), Low Profile Antenna, WLAN, Worldwide Interoperability for Microwave Access (WiMAX).**

I. Introduction

Two usually used protocols for wireless local area networks (WLANs) are wireless fidelity (Wi-Fi) and worldwide interoperability for microwave access (WiMAX), which promise higher data rates and increased reliability. A challenge in designing such multiple wireless communication protocol systems is to design compact, lowcost and broadband antennas with high gain as well as radiation characteristics. In order to satisfy these demands, inverted-F antenna (IFA) has been widely used in portable devices due to its compact, low profile configuration, ease of fabrication and favorable electrical performance. WiMAX can provide a long operating range with a high data rate for mobile broadband wireless access, faultless internet access for wireless users, so it becomes more popular gradually [1-4]. The rapid growing WLAN operating bands are IEEE 802.11 b/a/g at 2.4 GHz (2400–2484 MHz), 5.2 GHz (5150–5350 MHz) and 5.8 GHz (5725–5825 MHz) also the bands of WiMAX operation in the 2.5 GHz band (2500–2690 MHz), 3.5 GHz band (3300–3700 MHz) and 5.5 GHz band (5250–5850 MHz) [5–8]. To provide the increasing demand and cover up the 5.5 GHz WiMAX operating band a low profile antenna with improved gain is desired.

Internal wideband metal plate antenna for laptop application at 2.4 and 5.5 GHz [1], multi-band chip antenna for WiMAX 2.5/3.5/5.5 GHz operations [2], compact dual-wideband antenna for WLAN/WiMAX applications covering the 2.5/3.5/5.5 WiMAX band [3], multiband CPW- fed triangle-shaped monopole antenna covering 2.4, 5.2, 5.8 and 3.4 GHz WIMAX band [4], dual wideband printed monopole antenna for WiMAX bands 2.5/3.5/5.5 GHz [5], capacitively fed hybrid monopole/slot chip antenna for 2.5/3.5/5.5 GHz WiMAX operation in the mobile phone [6], broadband dual-frequency spider-shaped printed dipole antenna for 2.4/5 GHz WLAN [7], a planar CPW-fed slot antenna on thin substrate for 2.4 and 5 GHz WLAN operations [8], dual band–rejected micro-strip antenna for 2.5/3.5/5.5 GHz WiMAX [9], internal composite monopole antenna for laptop computer covering WiMAX band of 2.5/3.5/5 GHz [10], a compact and small printed monopole antenna for WLAN bands of 2.4 and 5.5 GHz [11] have been proposed.

In this paper, we present a promising inverted-F-L antenna (IFLA) for 5.5 GHz WiMAX applications.

II. Antenna Design

We examined the possibility of increasing antenna bandwidth, gain and maintaining the input impedance near about 50 Ω throughout the application bands with simplifying its structure, in designing the low profile antenna for 5.5 GHz WiMAX applications. Using method of moments (MoM's) in Numerical Electromagnetic Code (NEC) [12], we conducted parameter studies to ascertain the effect of different loading on the antenna performance to find out the optimal design where optimum segmentation of each geometrical parameter are used. The antenna is assumed to feed by 50 Ω coaxial connector. In our analysis we assume the copper conductor and the antenna was intended to be matched to 50 Ω system impedance. Fig. 1 represents the basic geometry of the IFA. Here one leg of IFA directly connected to the feeding and another leg spaced *s* from the ground plane. For the simulation we consider printed circuit board (PCB) with permittivity of ε_r=2.2, substrate thickness of 1.58 mm and the dimensions of the ground plane considered as 60 × 60 mm². When a load equal to an inverted-L is applied on the horizontal strip of IFA, the antenna structure of Fig. 2 titled as inverted-F-L antenna (IFLA).

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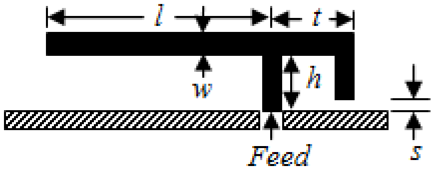


Figure 1. Inverted-F Antenna (IFA)

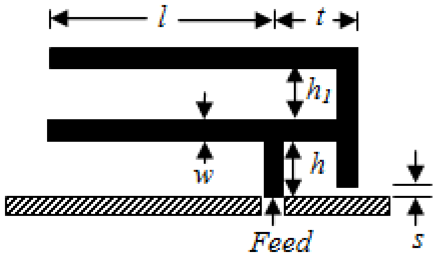
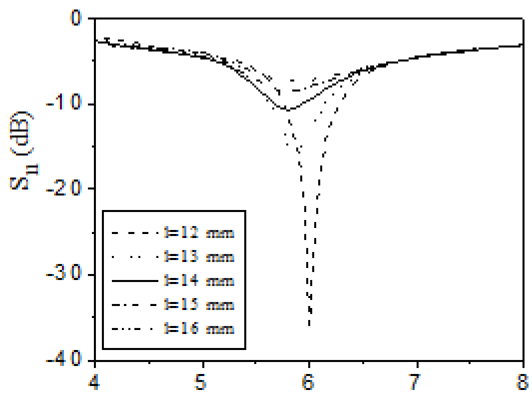
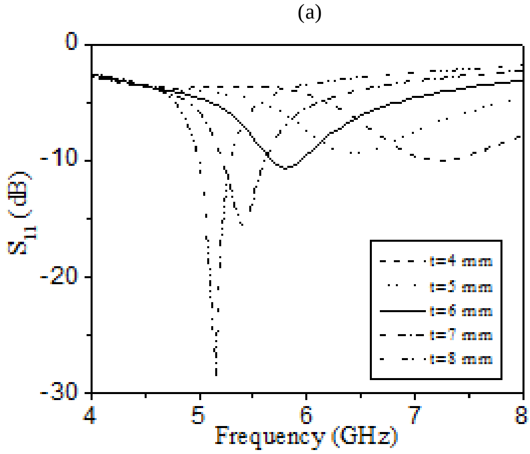


Figure 2. Inverted-F-L Antenna (IFLA)

Fig. 3 (a) and (b) shows the effects of length *l* and tap distance *t* on the return loss as a function of frequency on the IFA of Fig. 1. From the simulated results when *l=14 mm, t=6 mm, h=5 mm, w=2 mm* and *s=2 mm* the variation of return loss with frequency is like covering the whole 5.5 GHz operating band but the return loss stay above the required 10 dB level.



(a)



(b)

Figure 3. Return loss as a function of frequency (a) with different values of length, l (b) with different values of tap distance, t of the IFA of Fig. 1 when w=2mm.

For the antenna structure of Fig. 2 titled as inverted-F-L antenna (IFLA) the performance of return loss improves appreciably. The return loss variation of these two types of antenna structure is shown in Figure 4. Figure 5 shows the effects of *l* on the return loss of IFLA, when *w=2 mm, t=6 mm, h=5 mm,* h_1*=4 mm, and s=2 mm*. By considering the return loss, the best performance of the IFLA is obtained when *l=14 mm*. Now maintaining the length *l=14 mm* we continue our advance analysis on the tap distance *t* as shown in Fig. 6 and we observe that when *t=6 mm* the IFLA provides more negative return loss at the application bands than other values. Fig. 7(a) shows the effects of width *w* on return loss when the tap distance *t=6 mm* and length *l=14 mm.*

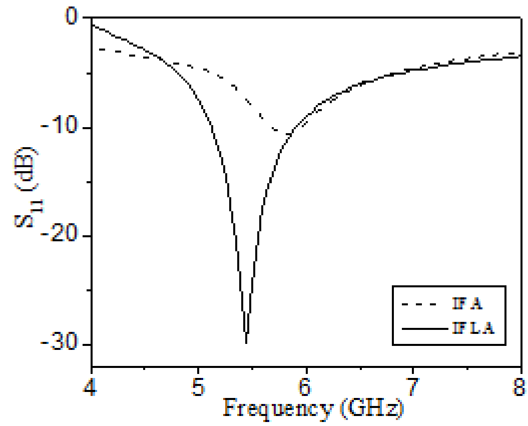


Figure 4. Return loss as a function of frequency for both antennas

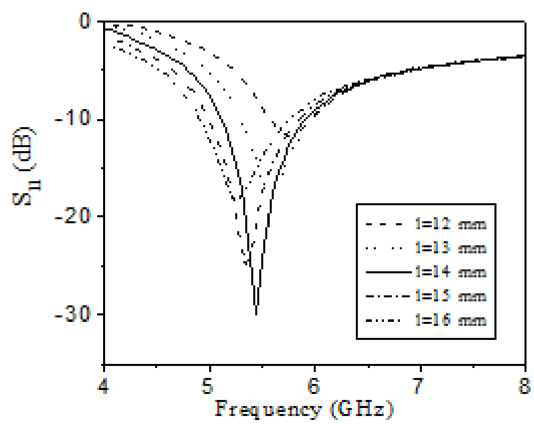


Figure 5. Return loss as a function of frequency with the different length *l* of the antenna structure of Fig. 2

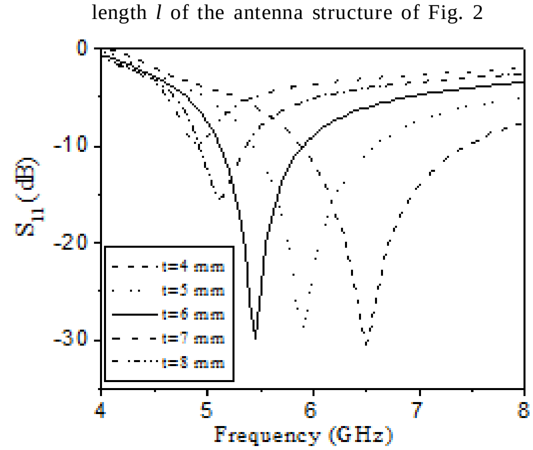


Figure 6. Return loss as a function of frequency with the different tap distance *t* of the IFLA of Fig. 2 when *l=14 mm*

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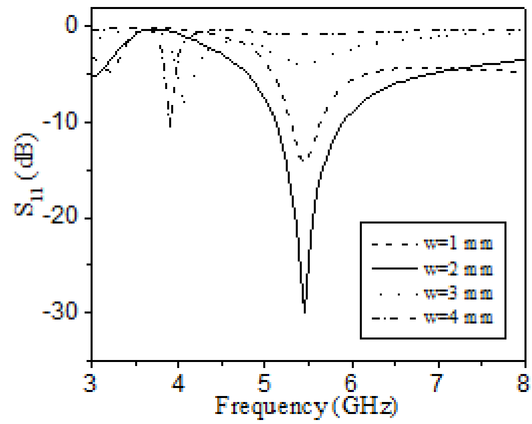
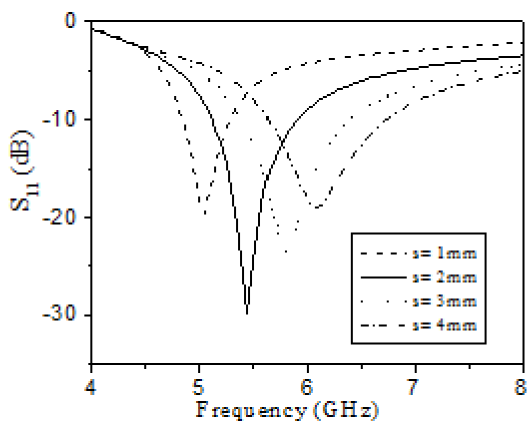
From Fig. 7 (a) we observe that the IFLA provide best return loss performance when *w=2 mm*. Moreover, we see that inverted-F-L antenna (IFLA) provides the desired return loss performance for the value of separation of *2 mm*, which is depicted in Fig. 7 (b). The effect of variation of the value of *h* and h_1 on the return loss performance of IFLA is shown in Fig. 8 (a) and (b) respectively. The optimized dimensions for best return loss performance of the proposed IFLA are listed in Table-I.

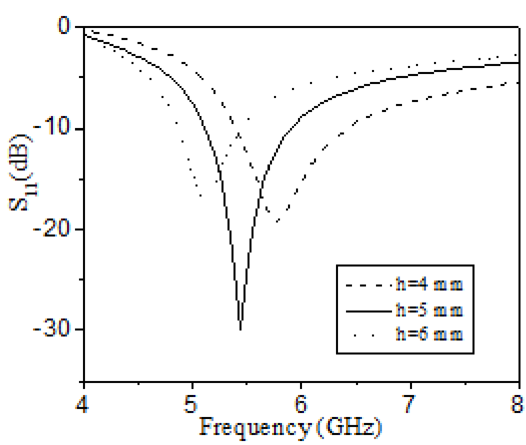


(a)

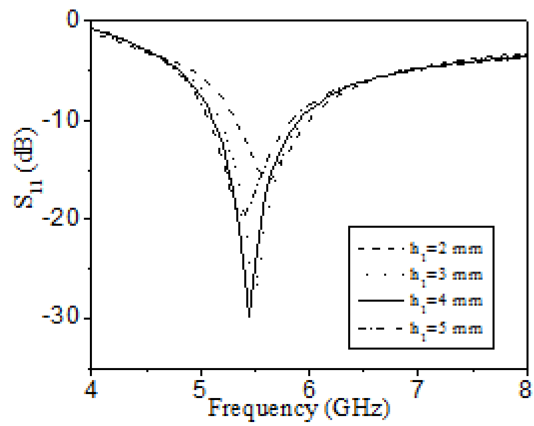


(b)

Figure 7. Return loss as a function of frequency (a) with different value of width w and (b) with different values of separation s of the IFLA of Figure 2 when t=6 mm and l=14 mm



(a)



(b)

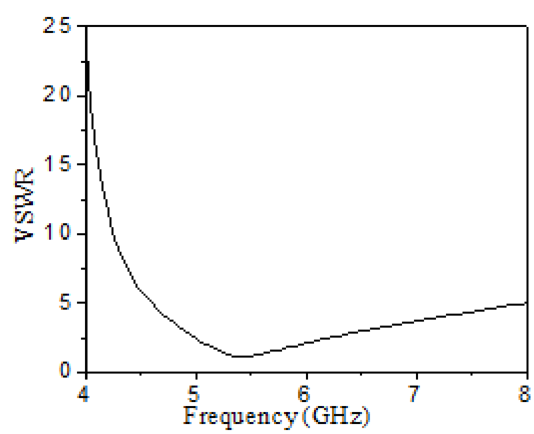
Figure 8. Return loss as a function of frequency (a) with different values of h (b) with different value of h_1 of the IFLA of Fig. 2 when t=6 mm and l=14 mm

TABLE I.
OPTIMIZED DIMENSIONS OF THE PROPOSED ANTENNA

Antenna Name	Antenna Parameters	Values (*mm*)	Dimension (*mm*^{2})
IFLA	*l*	14	9×20
	t	6	
	h	5	
	h_1	4	
	w	2	
	s	2	

III. NUMERICAL SIMULATION RESULTS

The proposed antenna is numerically analyzed using MoM's. The proposed IFLA has the return loss appreciable that is commonly required 10 dB level. Fig. 9 (a) and (b) shows the variation of voltage standing wave ratio (VSWR) and return loss respectively. The IFLA provides a bandwidth of 750 MHz (5150 ~5900 MHz) which covers the 5.5 GHz band and the peak value of return loss is -29.903 dB. The value of VSWR of IFLA varies from 1.4644 to 1.81311 within the operating band and obtained result indicates that the variation of VSWR is very low and it is near to 1 as shown in Fig. 9 (a).



(a)

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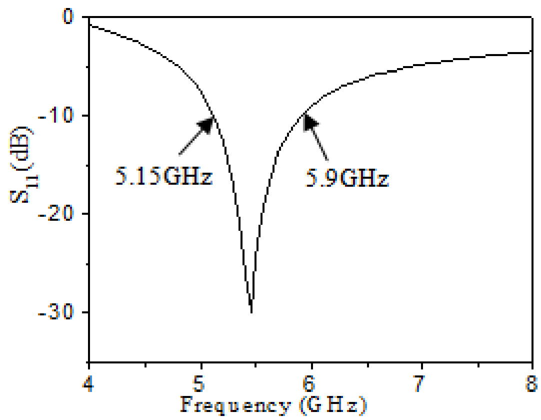
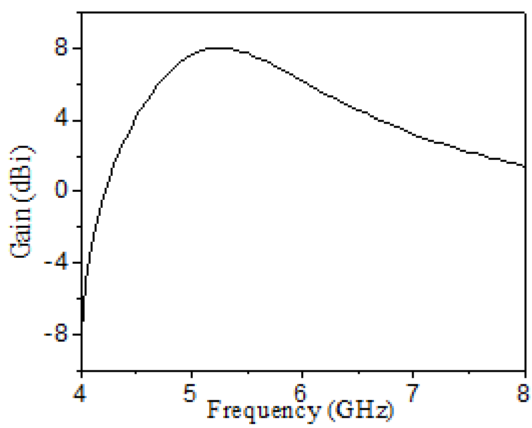
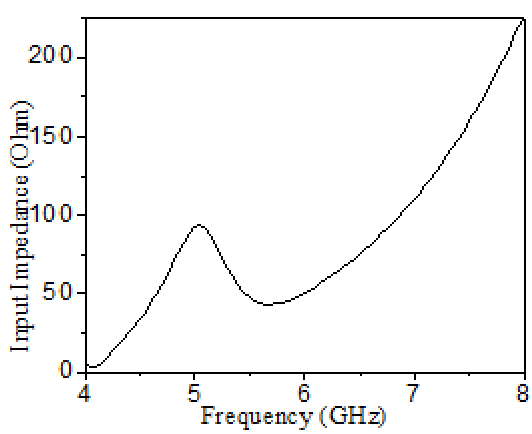


(b)

Figure 9. (a) VSWR and (b) Return loss variation of IFLA with frequency



(a)



(b)

Figure 10. (a) Total gain and (b) Impedance variation of IFLA with frequency

Fig. 10 (a) shows the gain characteristics of IFLA. The peak gains of IFLA is 8.04 dBi with less than 1.38 dBi gain variation within the 10 dB return loss bandwidth at 5.5 GHz band, which indicates that the antenna has stable gain within the operating bandwidth. Fig. 10 (b) represents the antenna input impedance variation and Fig. 11 represents the antenna phase shift causes due to the impedance mismatch as a function of frequency. The input impedance of IFLA is 47.8595 Ω at 5.5 GHz and the impedance varies within 72.9961 Ω to 43.1178 Ω throughout the operating bands that is the input impedance of the proposed antenna is near about 50 Ω. Also, according to the simulation study, the antenna offers a phase shift of 6.33063^0 at 5.5 GHz. The phase shift of IFLA is closer to 0^0 all over the antenna operating bandwidth. A comparison in gains between the proposed and reference antennas are listed in Table II. In overall considerations, it shows that IFLA can be used for the 5.5 GHz band. Fig. 12 shows the normalized radiation patterns of IFLA at 5.5 GHz band. The antenna's normalized total radiation in E and H-plane is almost omnidirectional at the 5.5 GHz WiMAX operating frequency.

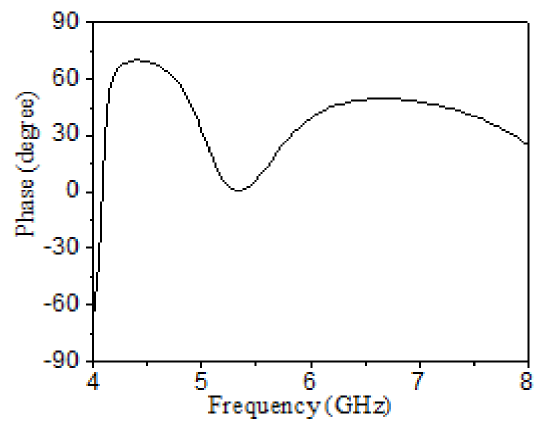


Figure 11. Phase variation of IFLA with frequency

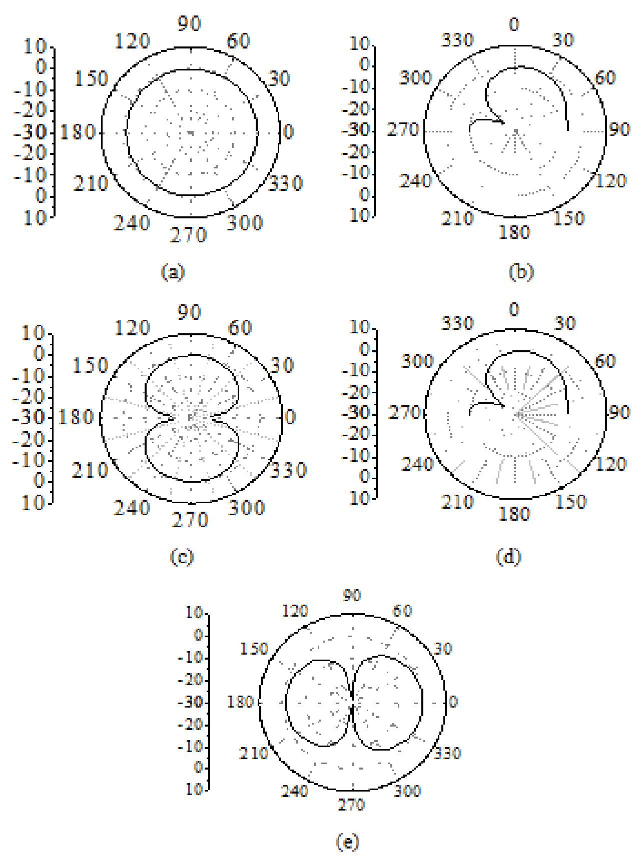


Figure 12. Radiation pattern (normalized) (a) total gain in E-plane, (b) total gain in H-plane, (c) horizontal gain in E- plane, (d) vertical gain in H-plane and (e) vertical gain in E- plane of IFLA at 5.5 GHz

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Internal metal-plate antenna, chip antenna, compact CPW-fed dual-wideband antenna formed by a rectangular ring monopole, printed monopole, hybrid monopole/slot chip, spider-shaped printed dipole, slot antenna, dual band–rejected micro-strip antenna, internal composite monopole, compact printed monopole antenna [1-11] have been proposed for WLAN or WiMAX or both applications suffers from gain limitations. From Table II it is observed that the gain of our proposed IFLA is much better than the previously proposed antenna for 5.5GHz band as well as IFLA has high gain and gain variation of only 1.38 dBi within the 10 dB return loss bandwidth at 5.5 GHz band.

TABLE III.
GAIN COMPARISON BETWEEN THE PROPOSED AND REFERENCE ANTENNAS

Antenna	Peak gain (dBi) at 5.5 GHz
IFLA (Proposed)	7.72
Internal metal-plate antenna [1]	4.6 –5.2
Chip antenna [2]	Around 2.0
Compact CPW-fed dual-wideband antenna [3]	2.6–4.1
Printed monopole antenna [5]	4.0
Hybrid monopole/slot chip antenna [6]	2.7–3.8
Spider-shaped printed dipole antenna [7]	4.6
Slot antenna [8]	(-1.58) – 0.78
Dual band–rejected micro-strip antenna [9]	2.5–4
Internal composite monopole antenna [10]	4.6–5.3
Compact printed monopole antenna [11]	2.4 - 3

CONCLUSIONS

A low profile inverted-F-L Antenna (IFLA) for 5.5 GHz WiMAX applications is proposed by means of numerical simulations. The proposed antenna has compact size of 9×20 mm^2 with bandwidth of 750 MHz (5150~5900 MHz). Moreover the peak gain of the antenna is amazingly high and the gain variation of the antenna within the return loss bandwidth are lower, means the antenna provides stable gain for the required applications. From the analysis antenna gain, radiation pattern, return loss and input impedance is suitable for the specified applications. Due to the compactness of the antenna, it is promising to be embedded within the different portable devices employing 5.5 GHz WiMAX applications.

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